Techno-Economic Assessment of Oxy-Combustion Turbine Power Plants with CO_2 Capture

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Paper by

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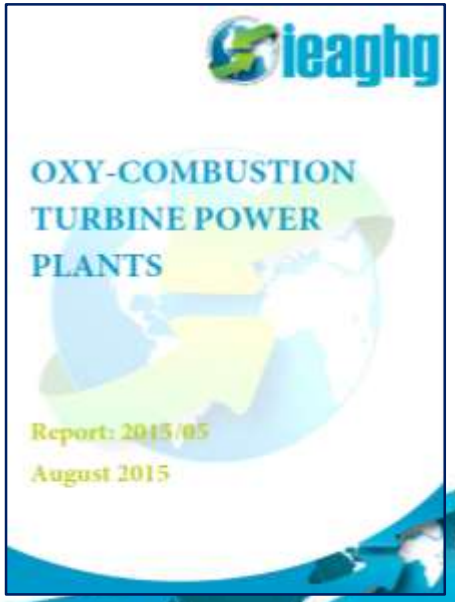
Outline of Presentation

- Background and scope of the study
- Cycle descriptions
- Cycle performance
- Costs
- Conclusion

Background to the Study

- Oxy-combustion turbines are not a new concept
- Increasing interest in oxy-combustion turbines
- Competitive efficiencies and costs are claimed for some cycles
- An independent techno-economic assessment is needed
- IEAGHG commissioned Amec Foster Wheeler and Politecnico di Milano to carry out a study
- IEAGHG report 2015/5, August 2015
  - Available within IEAGHG's member countries



Study Scope

- Review literature on oxy-combustion power generation cycles and their development status
- Assess performance of selected natural gas-fired plants
  - Detailed modelling of the gas turbine
  - Flowsheet modelling of the overall cycle
- Estimate capital and operating costs
- Sensitivity to technical and economic parameters and potential for future improvements
- Assess a coal gasification oxy-turbine power plant

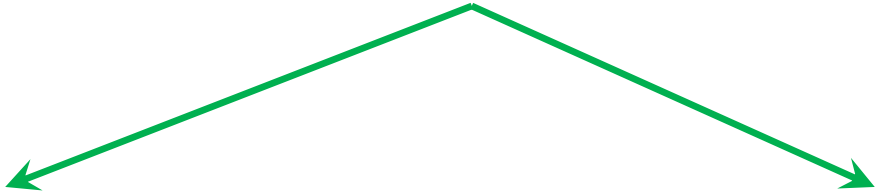
- Study uses the assumptions in IEAGHG's recent CCS plants studies

Cycles Selected for Detailed Assessment

Selection criteria

Expected efficiency

State of development/technical challenges



Cycles using recycled CO_2

- Semi-Closed Oxy-Combustion Combined Cycle (SCOC-CC)
- NET Power – Allam Cycle

Cycles using mainly H_2O

- S-Graz (2 versions)
- CES (3 versions)

Practical Activities

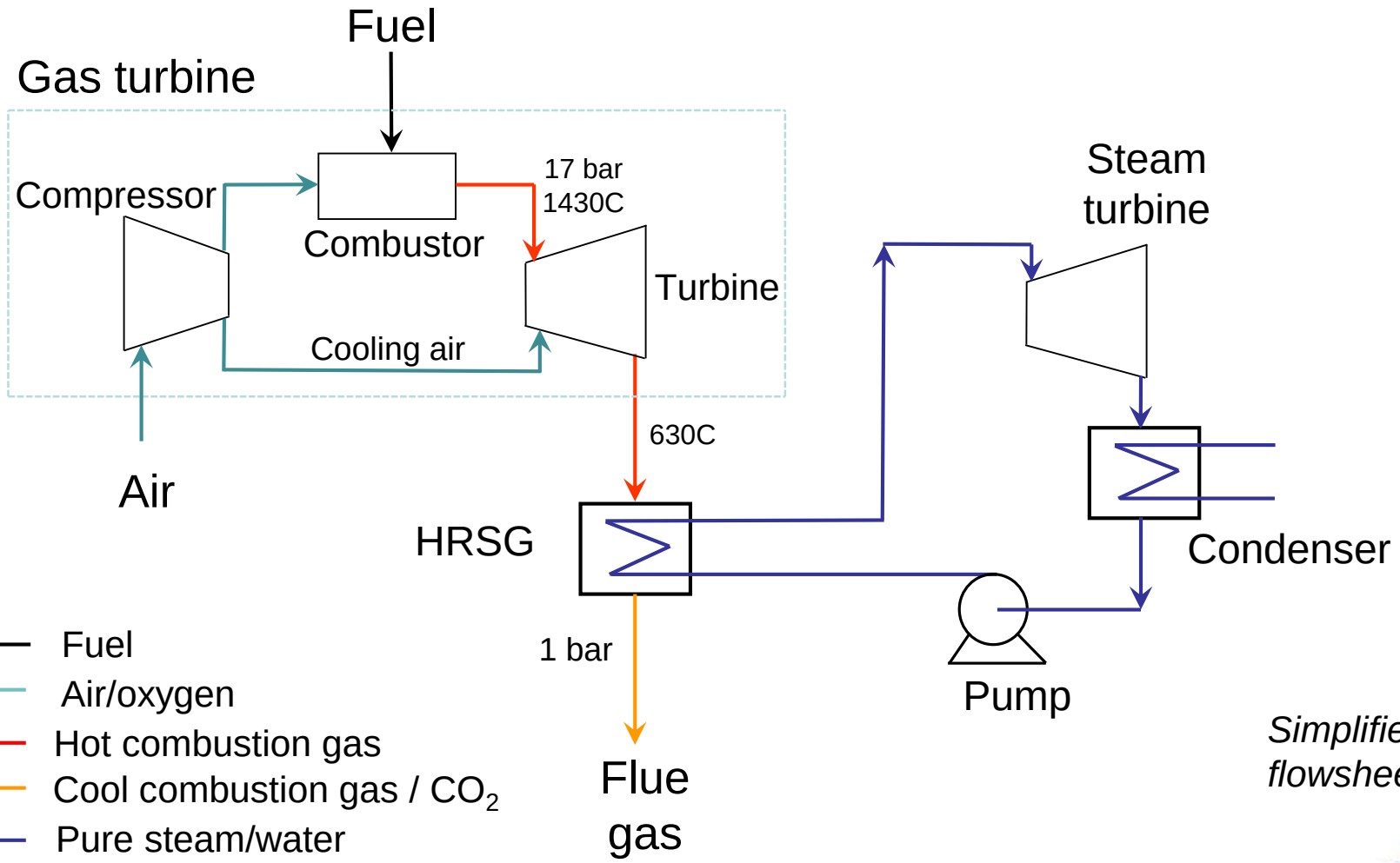
- CES has carried out Multi-MW component tests

CES 170MW_{th} gas generator

CES OFT-900 turbine

- NET Power combustor tests
- 50MW_{th} integrated plant scheduled to start commissioning in late 2016
  - Partnership with Toshiba, Exelon and Shaw Group

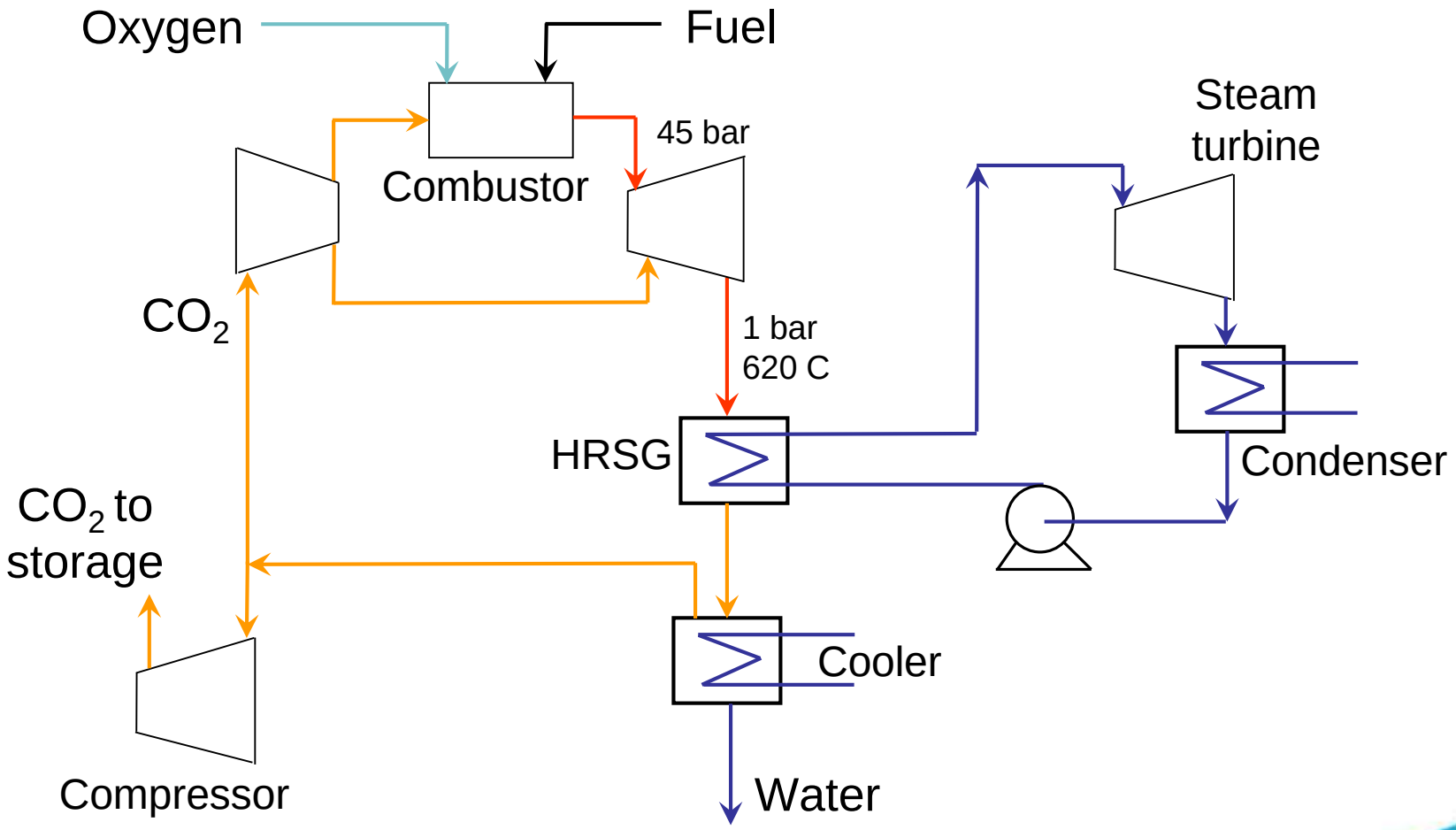
Conventional Combined Cycle



Simplified flowsheet

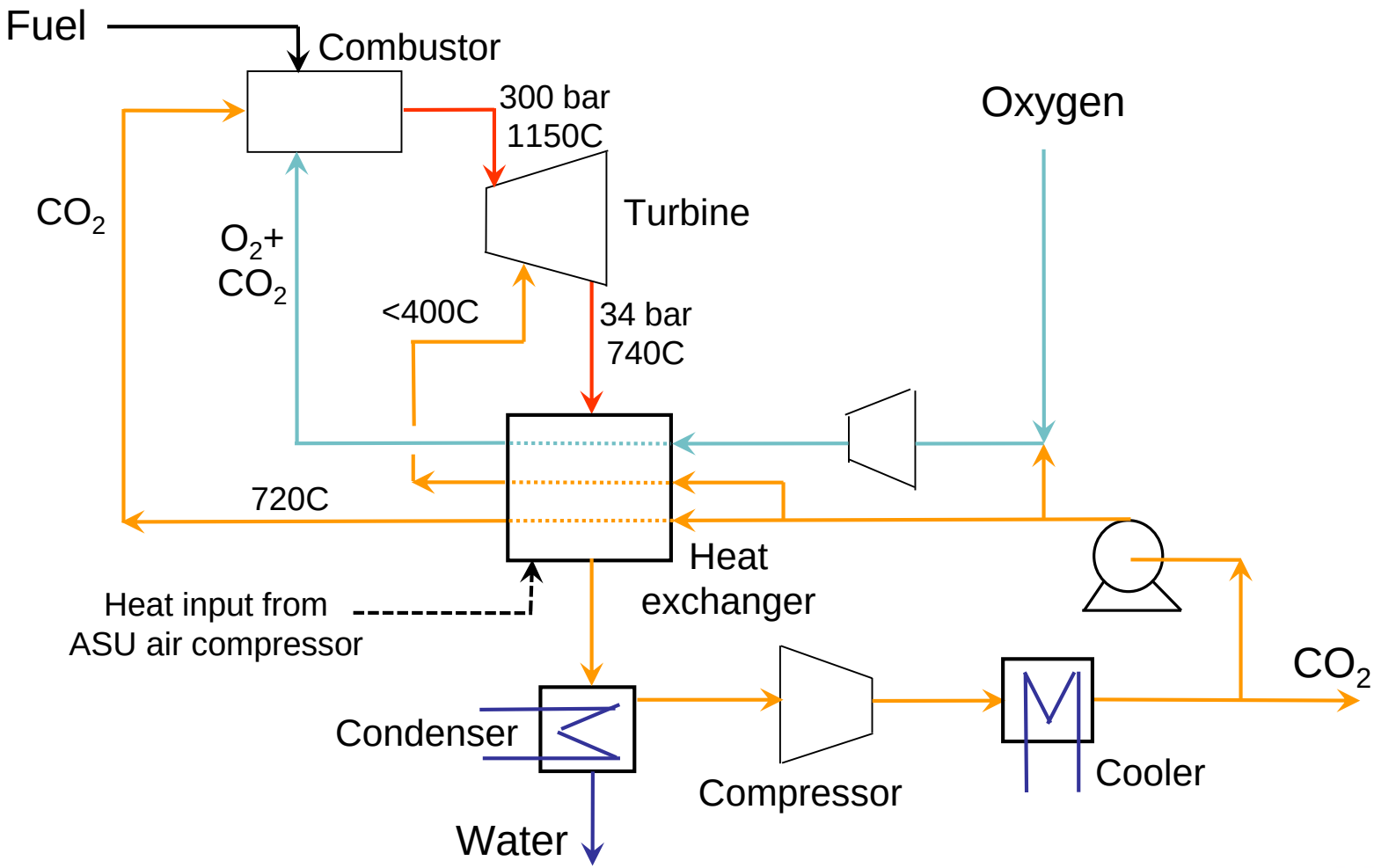
Semi-Closed Oxy-Combustion Combined Cycle (SCOC-CC)

Simplified flowsheet



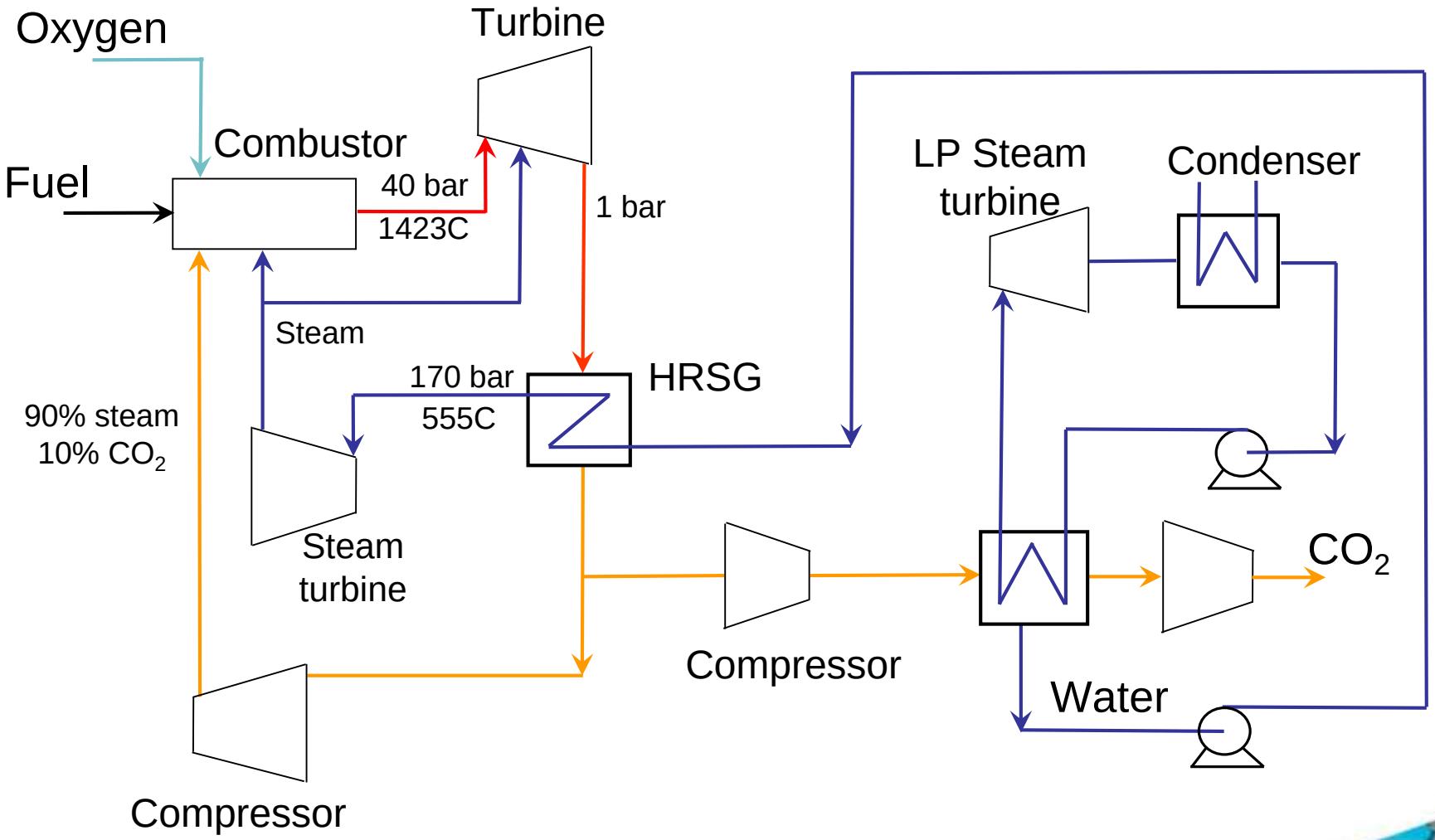
NET Power - Allam Cycle

Simplified flowsheet



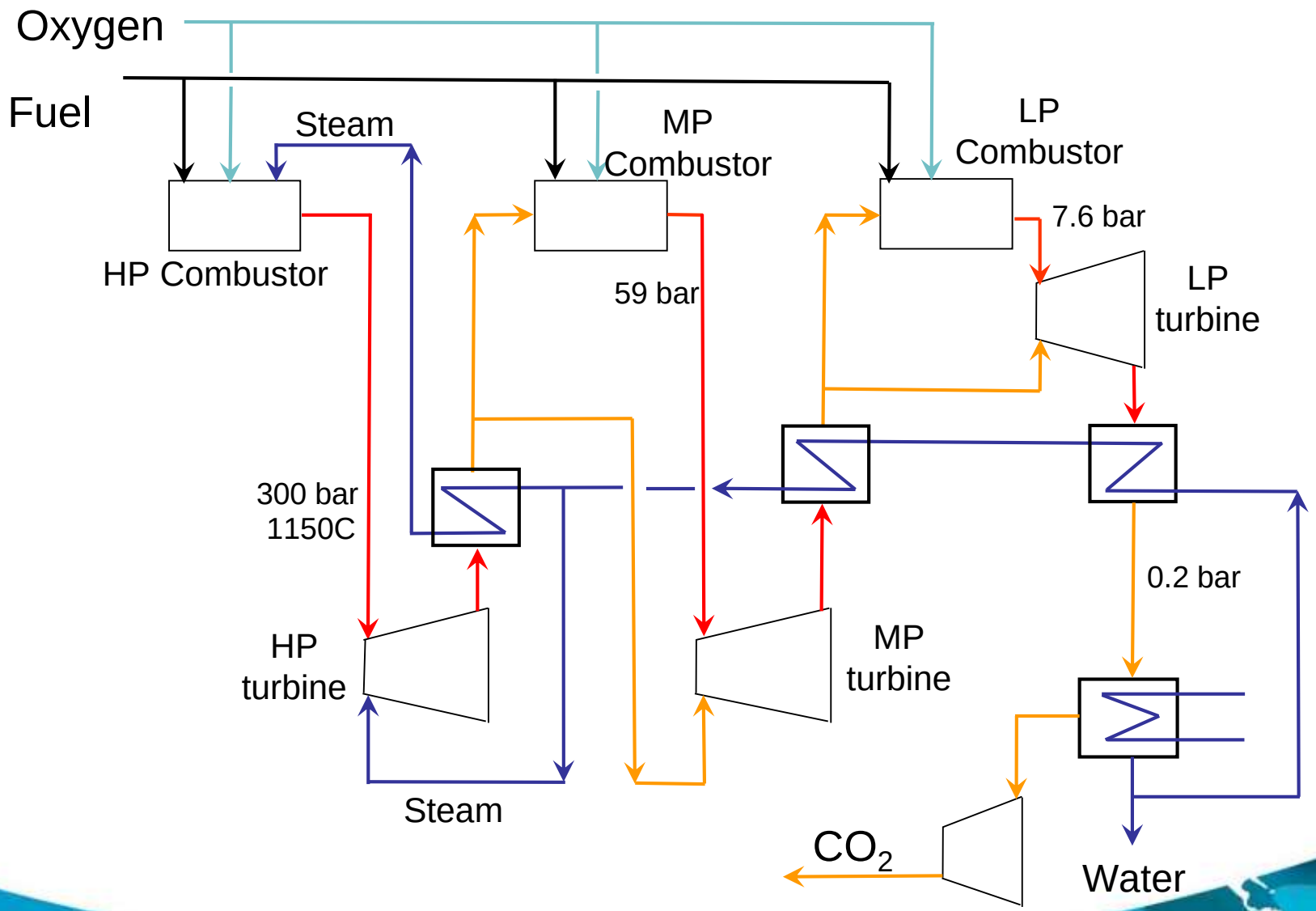
Modified S-Graz Cycle

Simplified flowsheet

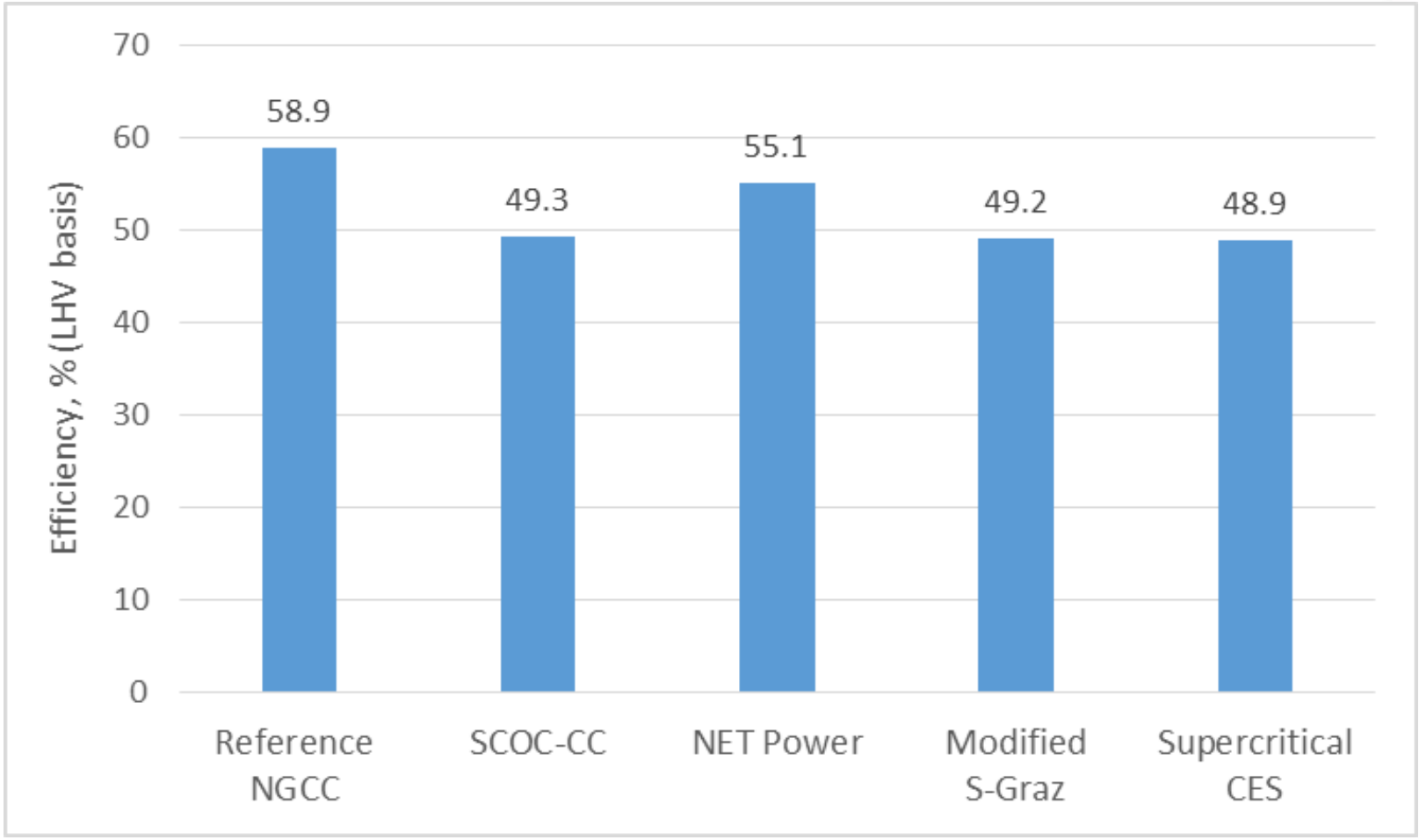


Supercritical CES Cycle

Simplified flowsheet

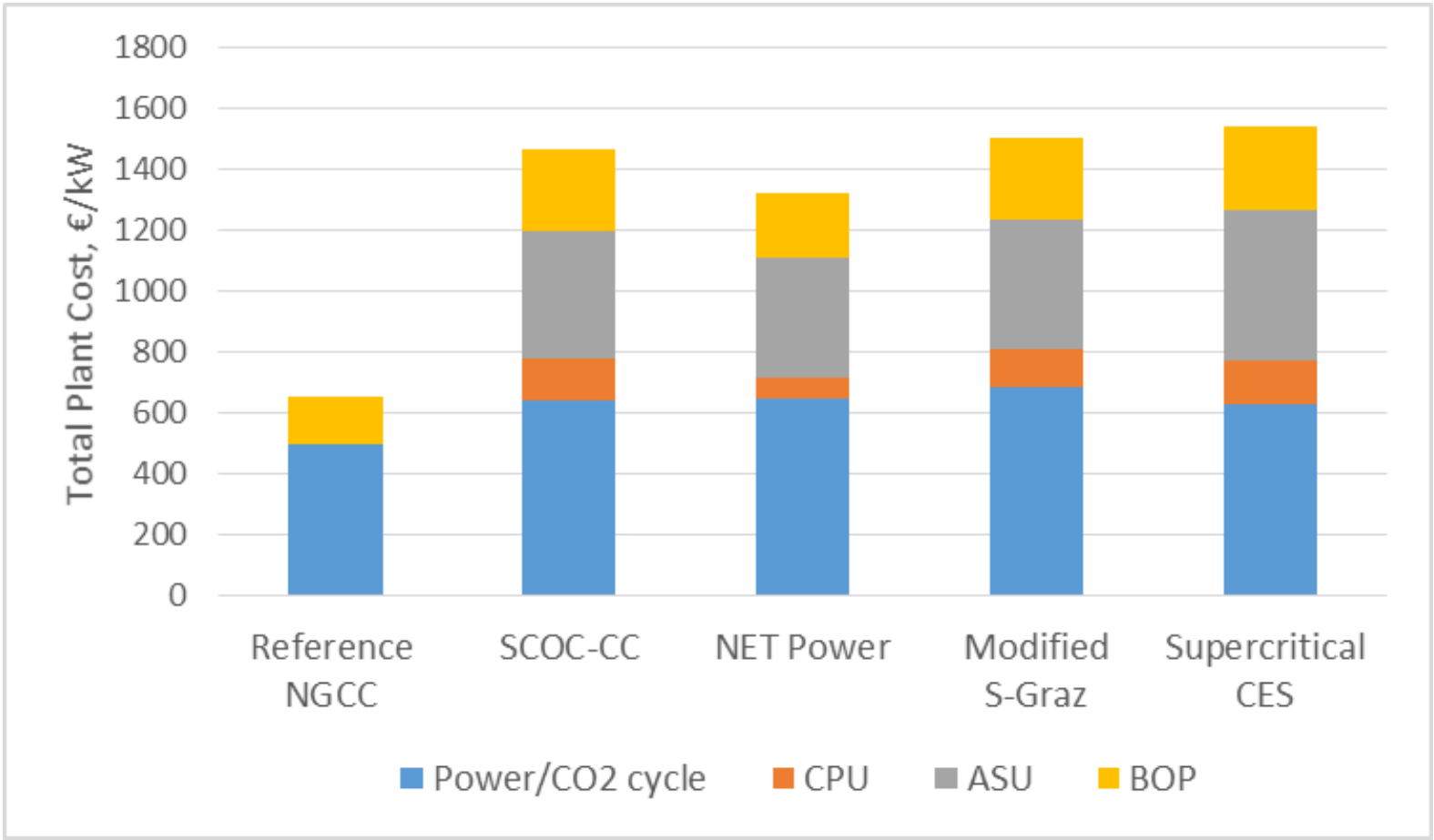


Thermal Efficiencies



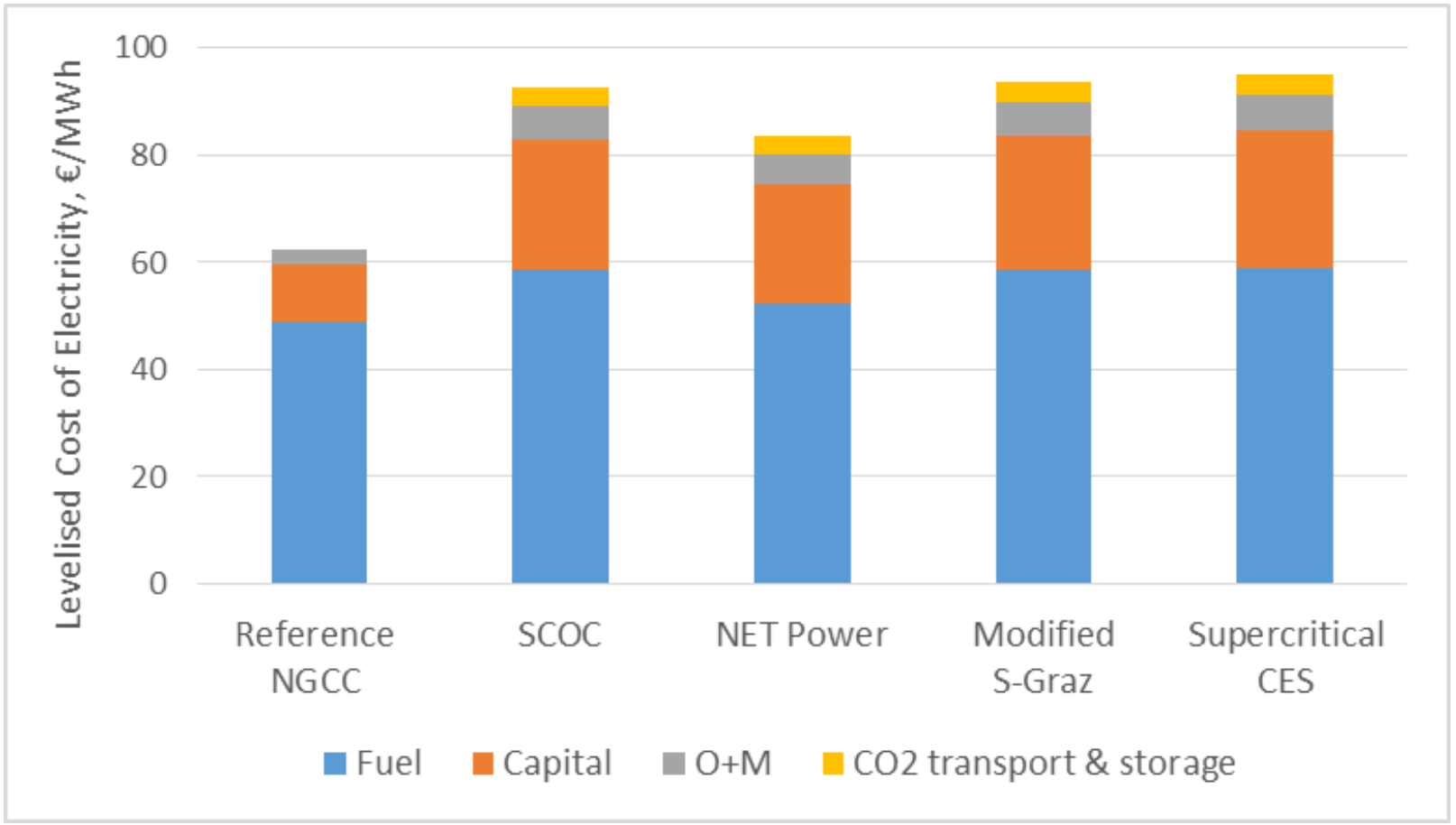
9C ambient temperature, Natural draught cooling towers

Capital Costs



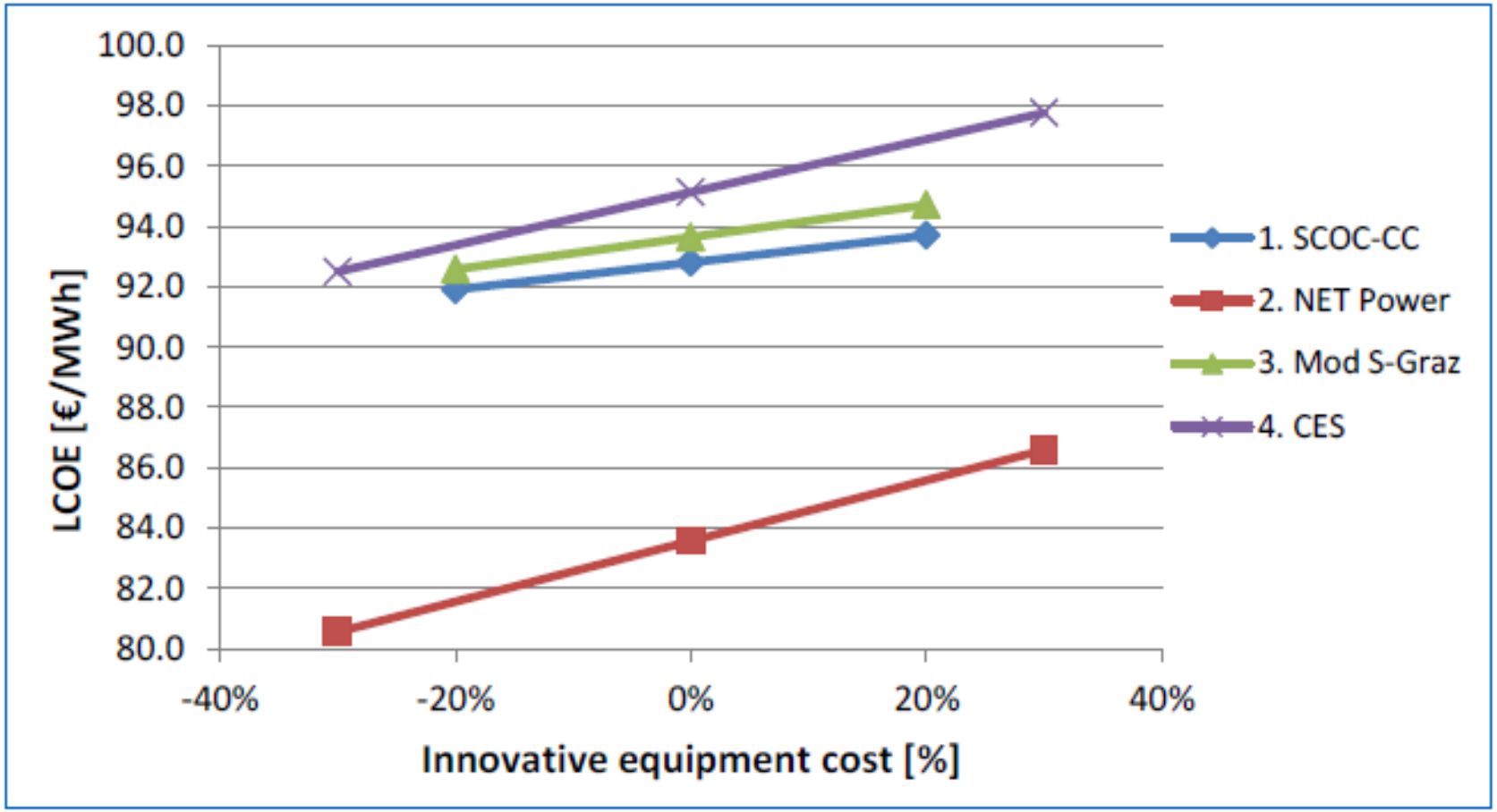
Total Plant Cost, excluding owner's costs and interest during construction, 2Q 2014, Netherlands location

Cost of Electricity

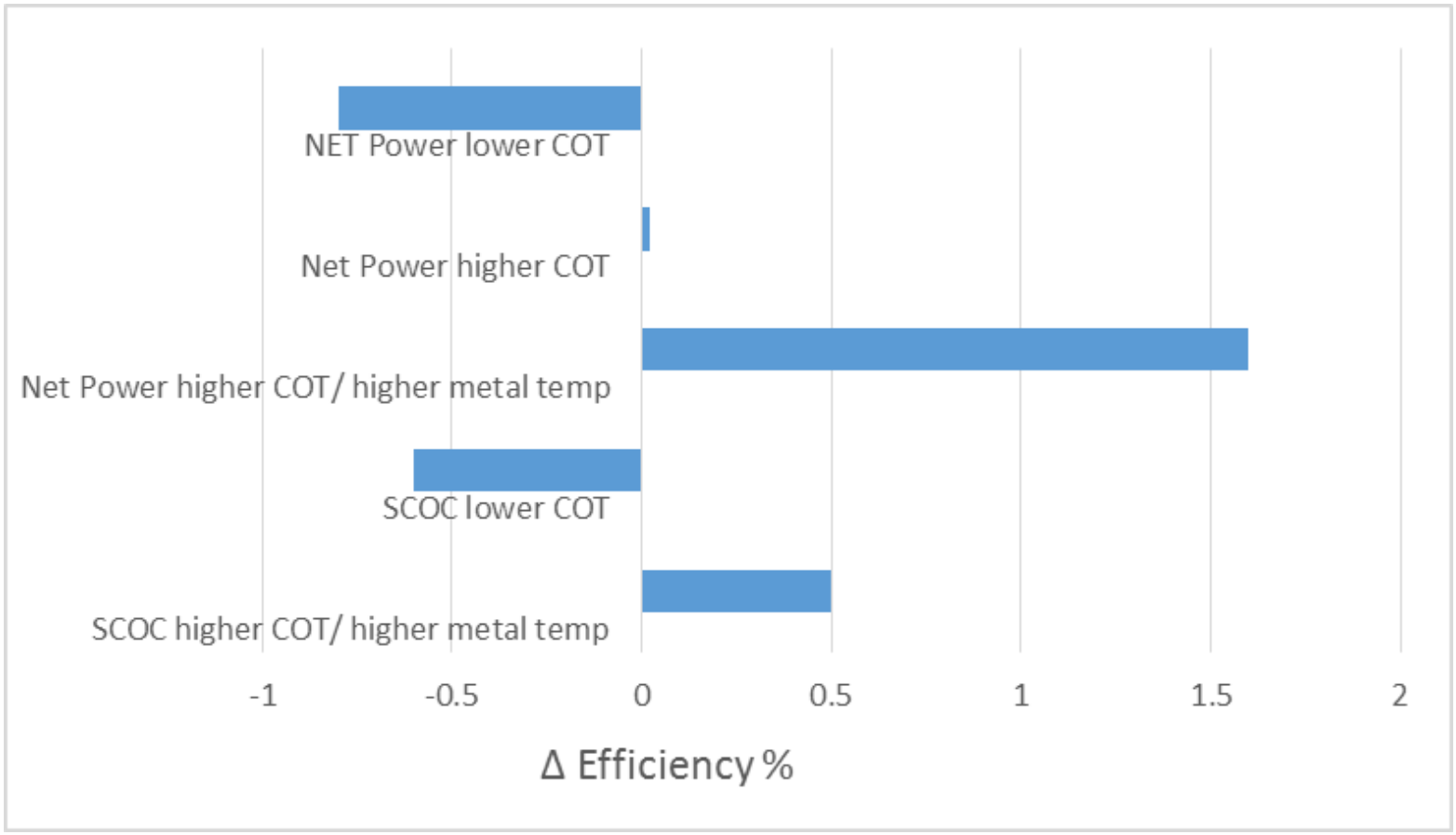


2Q 2014 costs, constant money values Netherlands location
Gas cost €8/GJ (LHV), 90% capacity factor, 8% discount rate, 25 year life,
€10/t CO_2 transport and storage cost

Sensitivity of LCOE to Novel Equipment Costs



Future Improvements



COT - Combustor outlet temperature: NET Power - 1150C base case, 1100/1200C low/high cases
SCOC - 1533C base case, 1453/1613C low/high cases

Turbine blade metal temperature: 860C base case, 950C high case

Sensitivity to CO_2 Capture Percentage and Purity

	CO_2 Capture %	CO_2 Purity %	Efficiency %	TPC €/kW	LCOE €/MWh	CAC €/t
Base case	90	99.8	55.1	1320	83.6	68
Membrane separation	98	99.8	54.7	1340	84.8	65
No purification	100	97.9	55.3	1270	82.7	58

Total Plant Cost, excluding owner's costs and interest during construction

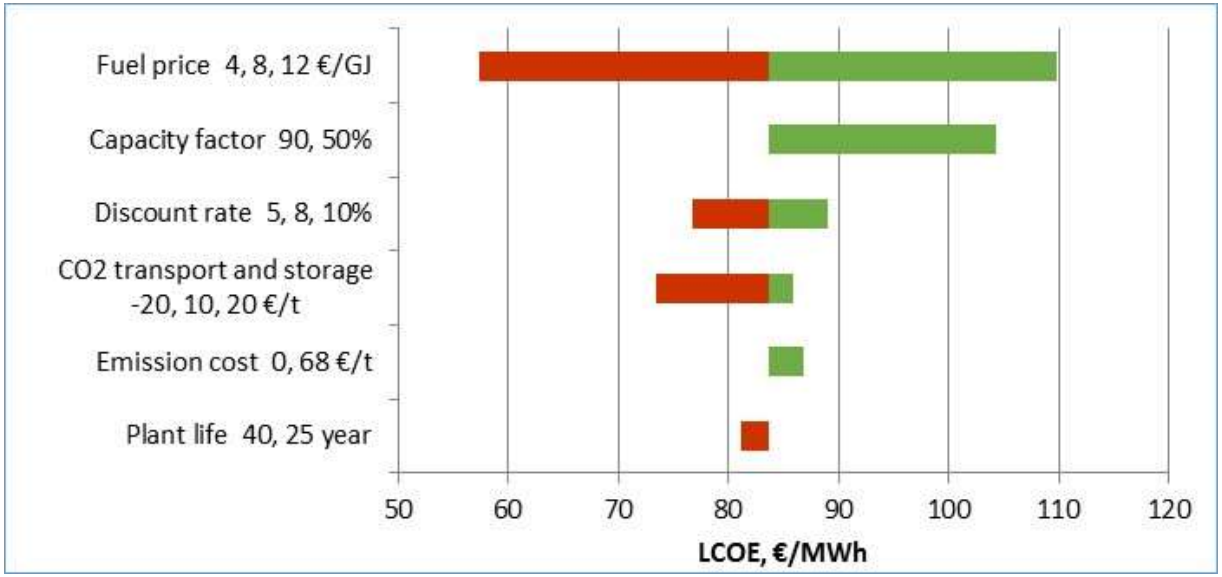
2Q 2014 costs, constant money values Netherlands location
Gas cost €8/GJ (LHV), 90% capacity factor, 8% discount rate, 25 year life, €10/t CO_2 transport and storage cost

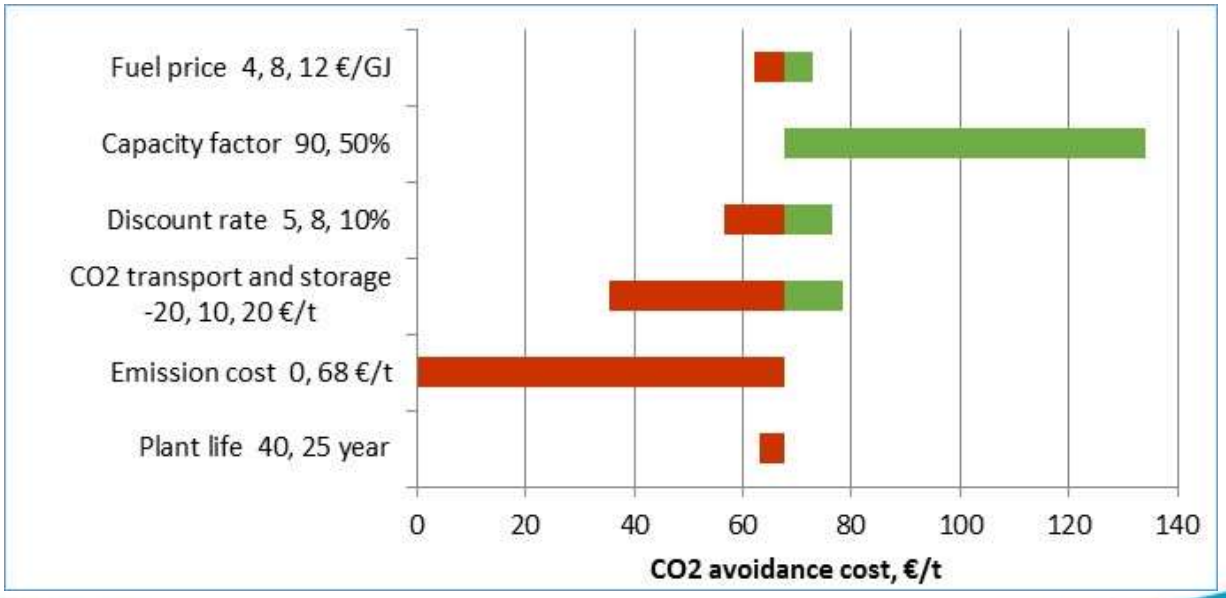
Lower abatement cost at higher percent capture

Other Sensitivities

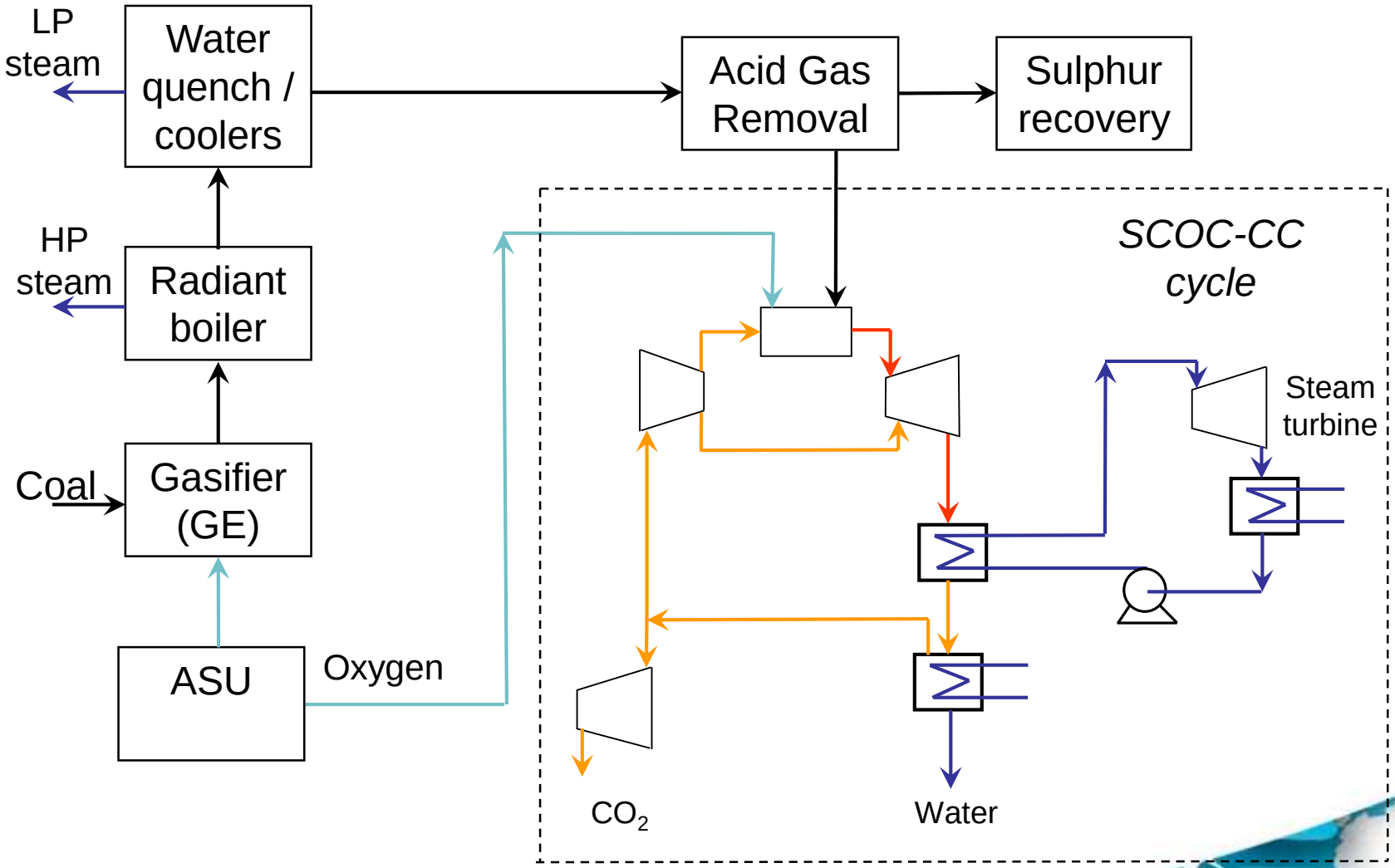
- High CO_2 natural gas (70%)
  - Quantity of CO_2 captured over 3 times higher
- Natural gas with high N_2 content (14%)
- Oxygen purity
- Higher ambient temperature (25C)
- Alternative cooling system (mechanical draught tower)

Economic Sensitivities





Gasification SCOC-CC Plant



Coal Gasification + Oxy-turbines

	SC-PC no capture	SC-PC post combustion capture	IGCC pre combustion capture	Gasification + SCOC-CC
Efficiency, % LHV	44.1	35.2	34.9	34.0
TPC, €/kWe	1450	2770	3070	3540
LCOE, €/MWh	52	95	114	127
CAC, €/t	-	65	96	115

Total Plant Cost, excluding owner's costs and interest during construction

Bituminous coal: 2.5 €/GJ (LHV), Discount rate: 8%,
25 year plant life, Constant €, CO_2 transport and storage: €10/t,
Capacity factor: 90% SCPC, 85% IGCC and SCOC

SCOC-CC costs are not competitive for coal

Need for Further Work

- Continue component and cycle development
- Operation of integrated large pilot plants
  - Achieve target efficiency
  - Achieve reliable operation
  - Demonstrate operating flexibility
- Cost reductions through optimisation, learning-by-doing and technology development
- Commercial roll-out to meet timescales for emission reduction

Conclusions

- Oxy-combustion turbines with CCS have the potential to achieve competitive efficiencies
  - Up to 55%
  - Higher than NGCC with post combustion capture (52%)
- Broadly similar capital cost, LCOE and cost of CO_2 avoidance to post combustion capture
- Other advantages
  - Potential for near 100% capture
  - Low water use
  - Small area
- Need for demonstration in integrated plants